SERGENT, HAUSKINS & BECKWITH

GROUNDWATER/SURFACE WATER

Technical Memorandum for the Environmental Assessment of the Bullfrog/Montgomery Shoshone Project Nye County, ~~Arizona~~ ? Nevada

Prepared for:

Bureau of Land Management
Tonopah Resource Area
Tonopah, Nevada 89049

Prepared by:

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Phoenix, Arizona 85009

SHB Job No. E87-301

Consulting Geotechnical Engineers

PHOENIX • ALBUQUERQUE • SANTA FE • SALT LAKE CITY • EL PASO • TUCSON

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1. INTRODUCTION

1.1 Purpose of Study

This report presents the findings of a hydrologic evaluation of the proposed Bullfrog/Montgomery Shoshone Project slated for development by St. Joe Gold Corporation in Nye County, Nevada. This evaluation was designed as technical support to the Environmental Assessment (EA) of the Bullfrog/Montgomery Shoshone Project, which is being completed by Environmental Research & Technology, Inc. (ERT) in third-party agreement with the Bureau of Land Management, Tonopah Resource Area Office.

The initial objective of this investigation was to first analyze specific hydrogeologic issues for the various mining components of the Bullfrog/Montgomery Shoshone Project. This analysis was supported by a hydrologic characterization of the project area, and culminated in an assessment of environmental consequences and a comparison of siting alternatives for waste rock disposal. Subsequent to these efforts, mitigative measures applicable to the various project components were developed to minimize the identified potential consequences.

1.2 Project Description

St. Joe Gold Corporation originally submitted a formal plan of operation during January of 1988. This plan

outlines the nature of the various project components, the operational details of the proposed mining activity, and methods to prevent or minimize the effect of the mining activity upon the environment, both during and after mining. Since the submission of this plan, several adjustments to the proposed action have been developed.

The following describes the proposed project and alternatives currently being considered and slated for full inclusion in the EA. The reader is referred to the Bullfrog/Montgomery Shoshone Project Plan of Operation for a more detailed description of project components and activities, and to the Fluor Daniel site plans (Drawing Nos. 470101-00-5-010A through 013A) and a March 31, 1988 Fluor Daniel memorandum from Mr. J. Nick, Jr. to Mr. F.P. Howald for the location and description of each of the waste rock alternatives. The alternatives are identified as Preferred Case, Option 1A, Option 2A and Option 3A.

1.2.1 <u>Proposed Project</u>

The Bullfrog/Montgomery Shoshone Project, as proposed by St. Joe Gold Corporation, would involve the construction, operation, ultimate reclamation and abandonment of two open pits, two waste rock disposal areas, milling and tailings disposal facilities, and

potential heap leach facilities. Additional ancillary facilities would include an electrical substation and transmission line, water supply system, access and haul roads, sanitary and solid waste disposal facilities, and fuel storage.

The Bullfrog and Montgomery Shoshone pits would produce a total of approximately 60 million tons of ore and 160 million tons of waste rock over a period of about 15 years. Waste rock would be placed in separate waste dumps associated with each pit. The mill and processing facilities would be located in the valley north of State Route (SR-374) and south of the Bullfrog Pit. The processing facilities will include primary crushing, secondary crushing, tertiary crushing, screening, conveying, grinding, leaching, adsorption, stripping, electrowinning and electrorefining. Tailings would be piped from the mill underneath SR-374 to a tailings impoundment where free liquid would either evaporate or be recirculated back to the mill as process water.

Heap leach facilities may be constructed and operated at some future date. If heap leach facilities are constructed, crushed ore would be conveyed under SR-374 and placed on leach pads. The solution from the heap leach would be collected in a pregnant pond, pumped

through the conveyor tunnel to the gold recovery circuit, collected in a barren pond adjacent to the mill and then pumped back to the heap leach pads for reuse.

1.2.2 Waste Rock Alternatives

A total of eight waste dump siting schemes are currently being considered for the Bullfrog Pit waste rock. A general description of each alternative is presented below:

- Preferred Case - This waste dump would be located north of SR-374 and south of the Bullfrog Pit. The waste dump would have its closest boundary 700 feet from the south pit wall and its farthest boundary 5,200 feet from the south pit wall.
- Option 1A - This alternative would move the western toe of the south dump further east. This would result in moving the dump out of the general site and wind passage of the town of Rhyolite. Multiple lifts will be necessary to achieve this alternative.
- Option 2A - This alternative places a waste dump due east of the Bullfrog Pit and immediately upgradient from the millsite. This area would not be large enough to contain all the waste rock; therefore, a south dump closely sited to the location of the proposed dumps for the Preferred Case and Option 1A would still be required. This site becomes the preferred option, if condemnation drilling indicates this area is barren.

- Option 3A - This alternative would place the waste dump on the south side of the SR-374 right of way. This siting requires adjustment of the leach pads and tailings pond locations. These adjustments are minor, with the leach pad complex shifted to the east and the tailings pond sited further downslope on the alluvial fan surface. A highway underpass would need to be constructed for this alternative.

The other four alternatives are similar to the ones described above, except that each of the waste dump sites would be expanded by 25 percent.

1.3 Scope of Work

In order to adequately address the technical issues involved in assessing the hydrologic impacts, a program was developed to investigate the characteristics, potential consequences and possible mitigative measures at the preferred mine site and the waste rock alternative sites. This program consisted of several phases which are described below.

- Acquisition & Review of Pertinent Geologic & Hydrologic Literature

  Sources of data included the U.S. Geological Survey, Bureau of Land Management, Nevada Department of Conservation and Natural Resources, Nevada Division of Water Resources, Nevada Soil Conservation Survey, Desert Research Institute, National Weather Service and the Beatty Water

Management Office. In addition, private and published geologic and hydrologic mapping and reports, local aerial photography, and a summary of well logs and condemnation logs within the area of investigation were also examined. Documents provided by St. Joe Gold Corporation, Hydro-Search, Inc., Dallhold Resources, Inc., Fluor Daniel, the National Park Service and the Beatty Town Advisory Council were reviewed prior to final preparation of this report.

° Field Investigation

A reconnaissance level survey of the site was performed in order to gain insight into the local hydrologic conditions. The general site locations of each of the major mine components were investigated to obtain site specific information. This investigation included a reconnaissance of the local springs.

° Personal Communications

Personnel from each of the agencies listed above were contacted in regard to obtaining data pertinent to the evaluation of the site. During the site visit, discussions were held with Joseph Rankin, Project Manager, and Doug Jorgenson, Project Geologist, of Dallhold Resources, Inc. regarding hydrogeologic conditions encountered during their mineral exploration program. Discussions were also held with Mr. Roger Oyler of the Bureau of Land Management, Tonopah Resource Area on the potential impacts the proposed project may have on water resources in the area and with Mr. Marvin Walker of the Beatty Water Management Office on present and future municipal water requirements for the town of Beatty.

2. AFFECTED ENVIRONMENT

2.1 Location, Physiography & Climate

2.1.1 Site Location

The Bullfrog/Montgomery Shoshone Project area is situated in the southern end of Nye County, Nevada (Figure 1), approximately 3 miles west of the town of Beatty.

The project area will encompass all or parts of:

Sections 31, 32, 35, T11S, R46E
Sections 1-18, 20-24, 26-28, T12S, R46E
Sections 7, 18, 19, T12S, R47E

The proposed facilities are sited in Sections 10, 14 through 16, 21 through 24, 26 and 27, T12S, R46E.

2.1.2 Regional Setting

The Bullfrog/Montgomery Shoshone Project lies within the Great Basin Region of the Basin and Range Physiographic Province (Stewart, 1980)*. This region is characterized by a series of north to south-trending

*References are listed at the end of this report.

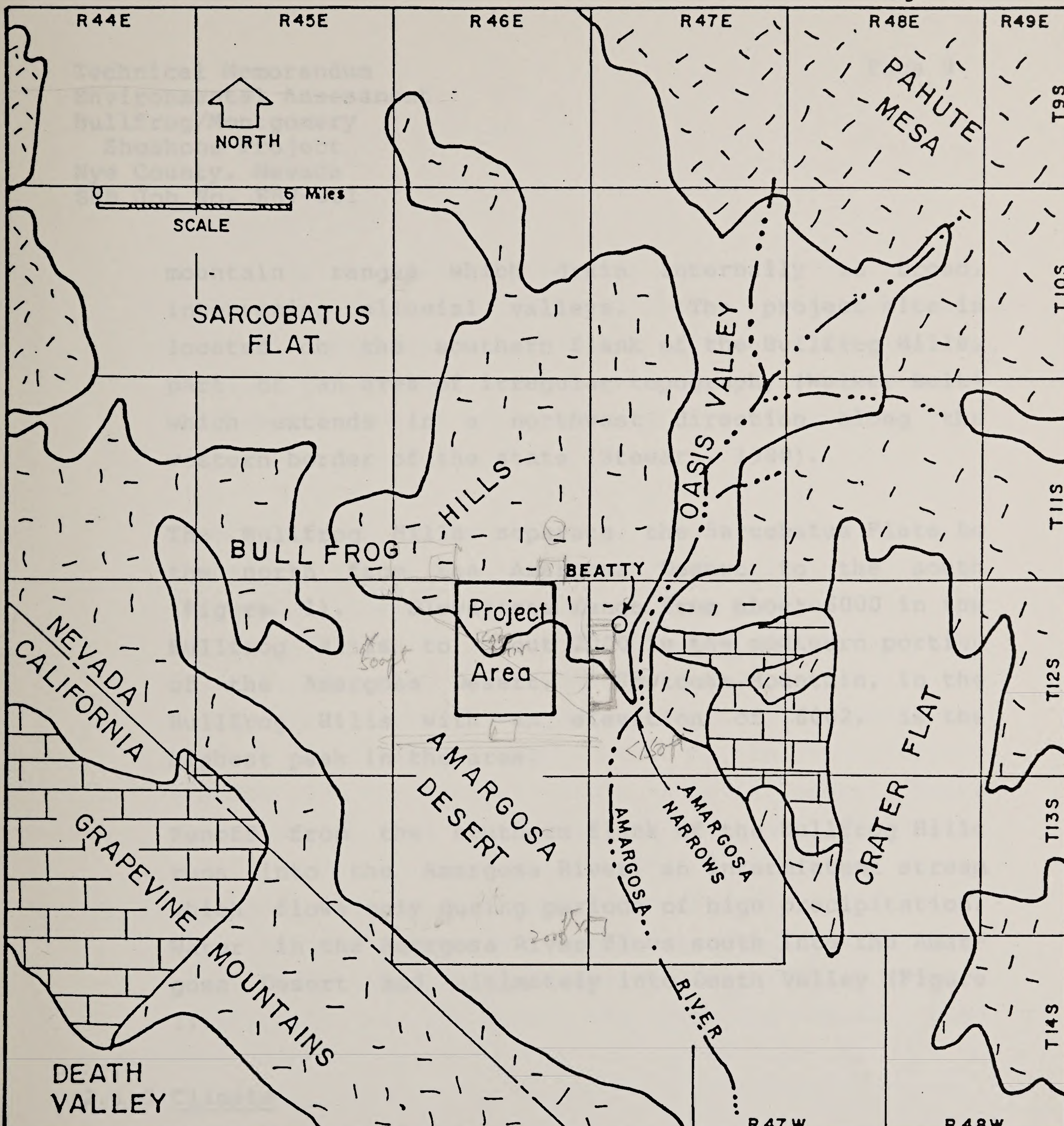

FIGURE 1

Generalized Regional Hydrogeologic Map

—Basin-Fill Deposits:	Quaternary alluvium and playa lake deposits.
—Noncarbonate Rocks:	Tertiary tuffs and flows, some Precambrian metamorphic and granitic rocks and upper Precambrian to Mesozoic clastic sedimentary rocks.
—Carbonate Rocks:	Paleozoic limestones and dolomites.

Modified and generalized from Thomas and others (1986), and Cornwall (1972).

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mountain ranges which drain internally to broad, intervening alluvial valleys. The project site is located on the southern flank of the Bullfrog Hills, part of an area of irregular topography (Walker Belt) which extends in a northwest direction along the western border of the state (Stewart, 1980).

The Bullfrog Hills separate the Sarcobatus Flats to the north from the Amargosa Desert to the south (Figure 1). Elevations range from about 6000 in the Bullfrog Hills to about 2000 in the southern portion of the Amargosa Desert. Sawtooth Mountain, in the Bullfrog Hills with an elevation of 6002, is the highest peak in the area.

Runoff from the southern flank of the Bullfrog Hills runs into the Amargosa River, an intermittent stream which flows only during periods of high precipitation. Water in the Amargosa River flows south into the Amargosa Desert and ultimately into Death Valley (Figure 1).

2.1.3 Climate

The climate of the Beatty area is characterized by low precipitation and humidity and high summer temperatures and evaporation (U.S. Weather Bureau, 1960,

1965). As is true throughout the Great Basin, precipitation increases with altitude, while daily and seasonal temperatures decrease. Summer precipitation usually occurs as local, high-intensity thunderstorms and showers, while winter precipitation occurs as snow or rain.

Beatty had a 44-year average annual rainfall of 4.60 inches. The precipitation is seasonally distributed throughout the year, with a monthly high of 0.71 inch in January and a low of 0.07 inch in June (Cornwall, 1972). Due to variations in storm patterns in the southwestern deserts, annual precipitation totals vary greatly from year to year. Based on the precipitation records in the Beatty area, a high annual total precipitation of 11.49 inches was observed in 1983.

The potential annual evaporation from lake and reservoir surfaces for the regional area was estimated to range from 60 to 82 inches (Meyers, 1962). This is roughly 12 to 18 times the rate of annual precipitation.

2.1.4 <u>Soils & Vegetation</u>

The surface soils in the project area are predominantly a mixture of clay, silt, sand and organic matter

with varying amounts of gravels and cobbles (SCS, 1988). Soil depths vary with slope and elevation, with bedrock outcrops common in the mountainous areas. Vegetation consists predominantly of sage brush and short grasses that cover about 50 percent of the mountainous areas and foothills. Vegetation in the playas is sparse and consists of several species of phreatophytes.

2.2 Regional Hydrogeologic Setting

The Great Basin region has a complex geologic history of sedimentation, igneous activity, orogenic deformation, continental rifting and extensional block faulting (Stewart, 1980). Extensional block faulting began about 17 million years ago and has formed the alternating mountain ranges and alluvium filled basins that characterize the area at the present time.

The project area is located in the southeastern portion of the Great Basin. This area is referred to as the Carbonate Rock Province of the Great Basin because of the thick sequence of Paleozoic limestone and dolomite in the region (Thomas and others, 1986). Lithologies within the Carbonate Rock Province can be divided into three major hydrostratigraphic units based on their

hydrologic properties: (1) carbonate rocks; (2) noncarbonate rocks; and (3) basin fill deposits (Figure 1).

2.2.1 Carbonate Rocks

The Paleozoic carbonate rocks are generally more permeable than the noncarbonate rocks because of the development of secondary permeability. Secondary permeability is most commonly developed by dissolution of carbonate minerals along structural features, such as faults, fractures and bedding planes (Thomas and others, 1986). The transmissivity of carbonate rocks may range from less than 13 square feet per day in the undeformed areas to more than 130,000 square feet per day in areas of intense fracturing and faulting (Eakin, 1966; Winograd and Thordarson, 1975).

Recharge to aquifers within the Carbonate Rock Province is supplied primarily through infiltration of precipitation and melting snow in the mountains and adjacent alluvial fans. Groundwater may then be trapped in hydrologically closed valleys or form part of a continuous groundwater flow system. Hydrologically closed valleys are generally found in areas that contain volcanic, granitic and sedimentary clastic rocks, which act as flow barriers to groundwater.

Discharge of groundwater in hydrologically closed valleys is primarily by evapotranspiration from the valley floor (Thomas and others, 1986).

2.2.2 Noncarbonate Rocks

Older noncarbonate rocks consist of Precambrian metamorphic and granitic rocks, and upper Precambrian to middle Cambrian clastic sedimentary rocks. Younger noncarbonate rocks that overlie the carbonate rocks consist of upper Paleozoic to Mesozoic clastic sedimentary rocks and Cenozoic volcanic rocks (Thomas and others, 1986). These rocks generally store and transmit only small amounts of water and act as barriers to groundwater flow or impermeable caps on regional aquifers.

2.2.3 Basin-Fill Deposits

Basin-fill deposits are located in structural depressions between the mountain ranges and generally range in age from Miocene to Quaternary. The basin fill deposits consist of unconsolidated to partly consolidated deposits derived from adjacent mountains and may reach a thickness of 10,000 feet (Thomas and others, 1986).

Continuous groundwater flow systems are generally formed by hydrologically connected basin fill reservoirs and/or adjacent underlying carbonate rocks or structural features. The basin fill reservoirs may be interconnected by saturated basin fill, permeable consolidated rock (generally carbonate rock), fractures or major rivers. Basin-fill deposits that are connected by underlying permeable carbonate rocks may form deep regional groundwater systems that may connect several valleys. Groundwater from these large flow systems is discharged by large springs, evapotranspiration in low-lying areas, and groundwater flow into rivers and lakes. Regional aquifers may have several discharge points along their flow path before reaching the lowest discharge area (Eakin, 1966).

2.3 Local Geologic Setting

The Bullfrog Hills area consists predominantly of Tertiary volcanic rocks with lesser amounts of Paleozoic and Precambrian rocks (Cornwall, 1972). The geologic features of the Bullfrog Hills and surrounding area are a result of both tectonic deformation and intense volcanic activity.

The volcanic rocks are thought to have been derived from a violent eruption of an underground magma chamber that

resulted in subsidence and formation of a large elongate caldera. The volcanic rocks are composed predominantly of rhyolitic ash flows and air-fall tuffs (Cornwall and Kleinhampl, 1964). The Bullfrog/Montgomery Shoshone Mine is located along the southeast limit of the caldera (Figure 1).

Older rocks of Precambrian and Paleozoic age are poorly exposed and have been folded and intensely faulted. The deformation is considered to be related to the Las Vegas shear zone and is expressed mainly by bedding plane thrusts (Cornwall and Kleinhampl, 1964).

The Precambrian age rocks are gneiss and schist which have been intruded by gneissic pegmatitic granite. The Paleozoic rocks are predominantly sedimentary quartzite, limestone, dolomite and shale (Cornwall and Kleinhampl, 1964). Carbonate rocks have a limited surface exposure in the project area, but may be present at moderate depths.

Older gravels, probably Pleistocene in age, are present as dissected fans along the mountain slopes. The Amargosa Desert to the south, the Oasis Valley to the east, and the Sarcobatus Flat to the north of the Bullfrog Hills are underlain by Quaternary alluvium. This alluvium is composed of gravel, sand and silt with

playa lake deposits occupying the low areas. In areas near the mountains, the recent deposits are relatively thin and overlie rock pediment surfaces, while in the valleys, the deposits may reach a thickness of several thousand feet or more (Cornwall, 1972).

2.4 Local Groundwater Conditions

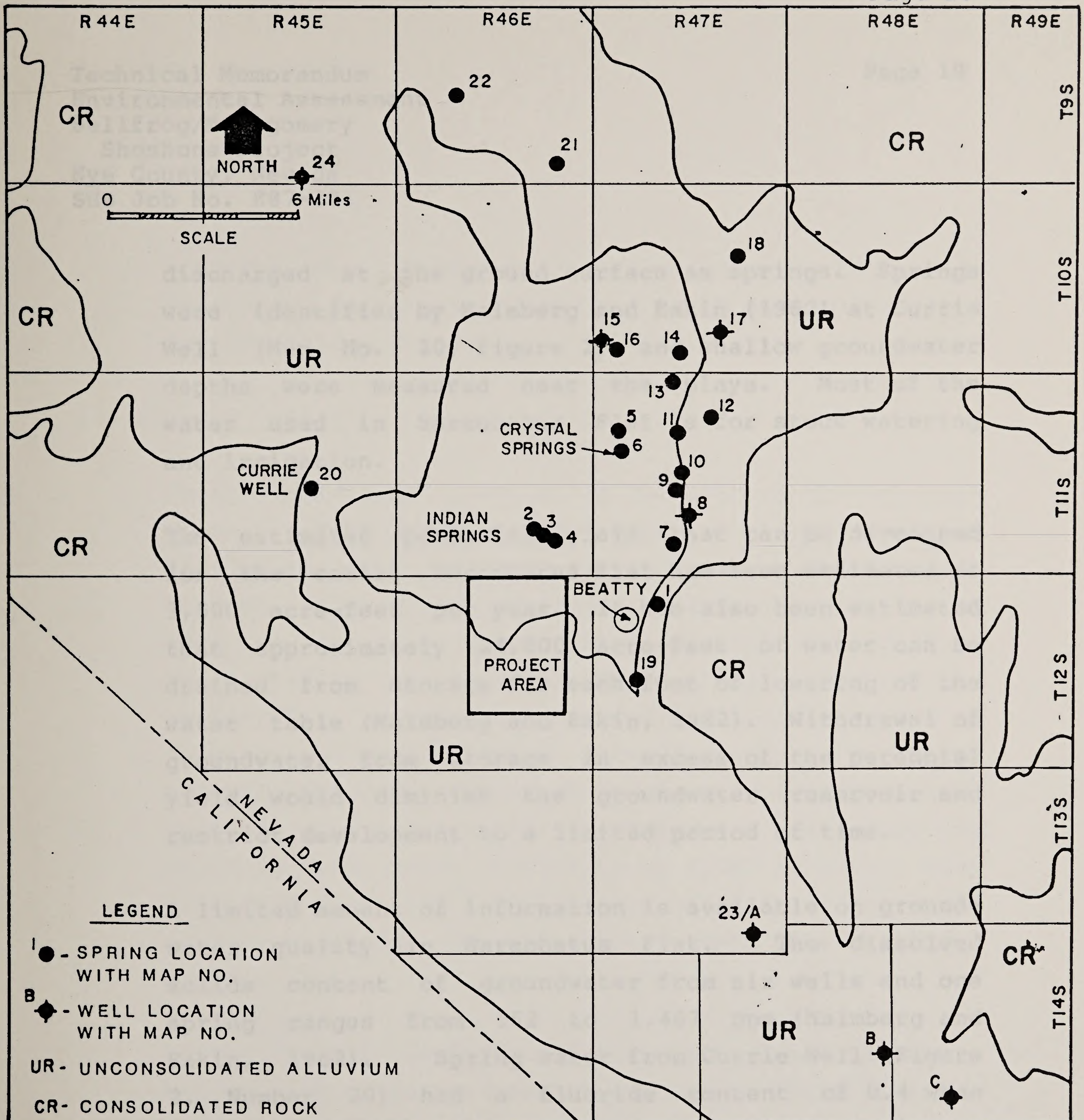
Of the three hydrostratigraphic units discussed in Section 2.2, the valley fill deposits appear to form the principal groundwater reservoirs in the project area. Cornwall and Kleinhampl (1961) indicate that the Paleozoic carbonate rocks generally have a low permeability, although some water is transmitted through secondary pathways. Groundwater also occurs in the Tertiary lava, tuff and welded tuff. Where saturated, they may contain a considerable amount of water, but the yield of wells developed in these rocks is generally low (Malmberg and Eakin, 1962). In general, water yields from the Tertiary volcanic and Paleozoic carbonate rocks is relatively small, unless large regional fracture systems are intercepted by wells.

Three areas containing valley fill deposits are located in the vicinity of the project site; Sarcobatus Flat, Oasis Valley and the Amargosa Desert (Figure 1).

2.4.1 Sarcobatus Flat

Sarcobatus Flat is located about 4 miles to the northeast of the project site and has a total surface area of about 380 square miles. The valley fill deposits consist of permeable lenses of sand and gravel interfingered with relatively impermeable lenses of silt and clay. Most wells penetrate only 200 to 300 feet into saturated deposits of the groundwater reservoir, with the total thickness of the deposit not known. The water-bearing strata appear to be hydraulically connected, with a single water table common to the area (Malmberg and Eakin, 1962). Groundwater recharge to the valley fill deposits at Sarcobatus Flat is predominantly by precipitation at higher altitudes, precipitation on the valley floor and possibly by underflow from surrounding areas. Discharge occurs principally by transpiration, evaporation and underflow out of the valley.

A groundwater study of Sarcobatus Flat by Malmberg and Eakin (1962) indicates that the water level gradient generally slopes from the periphery of the drainage basin towards the main playa, located in T9S, R44E. Depth to groundwater measurements taken during this study ranged from as deep as 61 feet at Well No. 24 (Figure 2) to several locations where groundwater



GEOLOGY FROM CORNWELL (1977) SPRING / WELL DATA FROM MALMBERG & EAKIN (1962), WALKER AND EAKIN (1963) AND CLASSEN (1983).

FIGURE 2

<u>Locations of Selected Springs & Wells</u>

discharged at the ground surface as springs. Springs were identified by Malmberg and Eakin (1962) at Currie Well (Map No. 20, Figure 2), and shallow groundwater depths were measured near the playa. Most of the water used in Sarcobatus Flat is for stock watering and irrigation.

The estimated perennial yield that can be developed for the entire Sarcobatus Flat has been estimated at 3,500 acre-feet per year. It has also been estimated that approximately 24,000 acre-feet of water can be drained from storage for each foot of lowering of the water table (Malmberg and Eakin, 1982). Withdrawal of groundwater from storage in excess of the perennial yield would diminish the groundwater reservoir and restrict development to a limited period of time.

A limited amount of information is available on ground-water quality in Sarcobatus Flat. The dissolved solids content of groundwater from six wells and one spring ranges from 352 to 1,407 ppm (Malmberg and Eakin, 1962). Spring water from Currie Well (Figure 2, Number 20) had a fluoride content of 0.4 when sampled as part of a regional study in 1962. Malmberg and Eakin (1962) indicate that based on classification systems used by the U.S. Salinity Laboratory (1954)

and the U.S. Department of Agriculture, the groundwater in Sarcobatus Flat may be of marginal quality for irrigation purposes.

2.4.2 Oasis Valley

Oasis Valley is located to the east of the Bullfrog Hills. The southern end of Oasis Valley is about 3 1/2 miles east of the project site at the Amargosa Narrows (Figure 1). Valley fill deposits underlie an area of about 60 square miles or about 15 percent of Oasis Valley (Malmberg and Eakin, 1962). Most of the valley fill consists of permeable material capable of storing and transmitting water, and may be up to several thousands of feet thick. The average annual recharge to Oasis Valley has been estimated by Malmberg and Eakin (1962) to be 1,800 acre-feet from groundwater inflow from adjacent valleys and about 250 acre-feet from precipitation within the drainage basin.

Virtually all the groundwater development in Oasis Valley has been confined to the narrow strip of alluvial fill adjacent to the Amargosa River. In this area, the depth to groundwater is usually within a few feet of the land surface. Away from the floodplain, the depth to water generally increases (Malmberg and Eakin, 1962).

The movement of groundwater in Oasis Valley can be inferred only in a general way because of the scarcity of existing data. In general, groundwater is thought to move from recharge areas in the mountains northeast of Beatty towards the Amargosa River, where it emerges as springs or seeps or moves as underflow towards the Amargosa Narrows.

Most groundwater development within Oasis Valley has been through the improvement of existing springs. A portion of the municipal water supply for the town of Beatty was at one time supplied by Beatty Springs, which is comprised of a group of six springs located about 1 mile north of the town (Map No. 1, Figure 2). Hot springs have been developed for recreational use at several locations, including Map No. 10, Figure 2 (Malmberg and Eakin, 1962).

Almost all of the groundwater discharge from Oasis Valley is by evapotranspiration and groundwater underflow to the Amargosa Desert through the Amargosa Narrows. In addition, a number of small springs in Oasis Valley discharge small amounts of water, most of which is ultimately lost to evaporation and transpiration. The most notable among the larger springs are the Beatty Springs, which generally discharge

between 100 to 200 gallons per minute (gpm). An estimated 400 acre-feet of groundwater discharge occurs as underflow through the bedrock gap in the Amargosa Narrows. The remainder of the discharge occurs as evapotranspiration.

High concentrations of fluoride in the municipal water supply has long been a concern for the town of Beatty. It is thought that the fluoride in the groundwater is derived from chemical weathering of Paleozoic carbonate rocks and chemical decomposition of fluoride-bearing volcanic rocks in the Bare Mountain area to the east of Beatty. In general, the lowest fluoride concentrations are found in groundwater derived from the Bullfrog Hills area on the west side of the Amargosa River, while the highest fluoride concentrations were found on the east side of the Amargosa River. Water from Indian Springs and Crystal Springs had the lowest fluoride concentrations (Malmberg & Eakin, 1962). Chemical analyses of water from several wells within Oasis Valley are presented on Table 1, and corresponding map numbers are shown on Figure 2.

The low relief of the Bullfrog Hills and the small size of the basins limit the recharge to the groundwater reservoir. The amount of annual recharge to the Indian Springs and Crystal Springs areas is about 40

TABLE 1

Chemical Analyses of Well & Spring Water

Map[1] No.	Sectional Description	Source of Data	Date of Sampling	Depth of Well	Estimated Spring (2) Discharge	Temperature F°	pH	Specific[3] Conductance	Hardness[4] CaCo3	TDS[5]	Silica	Iron
1	S12/47-5ca	a[7]	2-22-56	--	100-200	76	8.2	552	43	368[10]	68	--
2	S11/46-26cb	a	3-15-62	--	--	65	8.5	230	24	198	--	0.08
3	S11/46-26ca	a	2-22-56	--	--	60	7.9	319	24	224[10]	52	0.22
4	S11/46-26dc	a	3-15-62	--	1-2	65	8.2	330	36	228	--	Neg.
5	S11/47-7dc	a	2-22-56	--	--	--	7.7	399	64	266	55	0.0
6	S11/47-18aa	a	3-14-62	--	2-3	69	8.1	240	72	171	--	Neg.
7	S11/47-33ba	a	3-14-62	--	25	88	8.4	470	14	330	--	Neg.
8	S11/47-28aa	a	3-14-62	--	--	--	8.1	1,500	120	1,071	--	Neg.
9	S11/47-21ac	a	3-14-62	--	100	97	7.9	1,100	84	784	--	Neg.
10	S11/47-16dc	a	3-14-62	--	--	97	7.9	750	48	526	--	Neg.
11	S11/47-9ac	a	3-14-62	--	10	59	8.0	1,000	84	712	--	Neg.
12	S11/47-10ab	a	3-14-62	--	50-75	71	8.3	590	52	413	--	Neg.
13	S11/47-4bb	a	3-14-62	--	7	65	8.4	760	88	532	--	Neg.
14	S10/47-33a	a	3-14-62	--	15	75	8.0	760	60	532	--	Neg.
15	S10/47-30c	a	3-14-62	25	--	--	7.9	590	92	412	--	Neg.
16	S10/47-30d	a	3-14-62	--	25	58	8.1	680	88	427	--	Neg.
17	S10/47-27a	a	3-14-62	6	--	58	8.0	1,000	63	712	--	Neg.
18	S10/47-14b	a	3-14-62	--	50	72	8.5	550	20	384	--	Neg.
19	S12/47-20bb	a	3-16-62	--	--	64	8.1	1,200	100	853	--	Neg.
20	S11/45-22b	a	3-15-62	--	1/4	--	7.6	500	144	352	--	Neg.
21	S9/46-35a	a	3-21-62	--	--	72	8.2	610	52	427	--	Neg.
22	S9/46-20a	a	3-21-62	--	--	72	8.2	810	52	568	--	Neg.
23/A	S13/47-35a	b[8]	7-12-62	573	--	84	7.6	---	--	---	1.17[9]	---

FOOTNOTES:

(1) Refer to Figure 2 for Locations.
(2) Estimated in Gallons Per Minute.
(3) Micromhos at 25°C; computed by dividing solids content by .07. ? .065
(4) Calcium, Magnesium.
(5) Total Disolved Solids as Residue.
(6) Calculated.
(7) Malmberg and Eakin, 1962.
(8) Classen, 1983.
(9) Equivalents Per Million.
(10) Residue at 180°C.

Note: All results in parts per million unless otherwise specified.

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TABLE 1 (Cont'd.)

Chemical Analyses of Well & Spring Water

Map[1] No.	Sectional Description	Source of Data	Calcium	Magnesium	Sodium	Sodium[6] & Potassium	Potassium	Bicarbonate	Carbonate	Sulfate	Chloride	Fluoride	Nitrate
1	S12/47-5ca	a[7]	14.0	1.9	106	---	5.8	194	0.0	69	27	4.0	0.8
2	S11/46-26cb	a	4.8	2.9	---	76	---	115	---	62	17	0.2	8.5
3	S11/46-26ca	a	8.0	1.0	62	---	2.0	131	0.0	22	16	0.5	6.7
4	S11/46-26dc	a	8.0	3.9	---	64	---	139	---	24	18	0.5	14.0
5	S11/47-7dc	a	21.0	2.9	58	---	3.0	147	0.0	27	24	0.7	12.0
6	S11/47-18aa	a	22.0	3.9	---	57	---	151	---	14	27	0.4	23.0
7	S11/47-33ba	a	4.8	0.5	---	96	---	176	---	34	31	4.1	Neg.
8	S11/47-28aa	a	40.0	4.9	---	226	---	532	---	19	103	1.2	3.0
9	S11/47-21ac	a	27.0	3.9	---	181	---	393	---	48	75	4.5	Neg.
10	S11/47-16dc	a	18.0	0.5	---	144	---	266	---	72	48	4.2	Neg.
11	S11/47-9ac	a	24.0	5.8	---	177	---	383	---	34	78	3.8	Neg.
12	S11/47-10ab	a	19.0	1.0	---	90	---	188	---	24	48	2.9	Tr.
13	S11/47-4bb	a	27.0	4.9	---	126	---	310	---	29	52	2.2	6.5
14	S10/47-33a	a	24.0	0.1	---	127	---	275	---	14	65	1.9	4.0
15	S10/47-30c	a	29.0	4.9	---	110	---	266	---	34	49	1.5	11.0
16	S10/47-30d	a	27.0	4.9	---	105	---	278	---	14	48	3.2	7.6
17	S10/47-27a	a	24.0	2.0	---	136	---	288	---	34	66	3.7	Neg.
18	S10/47-14b	a	6.0	1.0	---	117	---	212	---	24	54	3.8	Tr.
19	S12/47-20bb	a	32.0	4.9	---	184	---	400	---	48	86	4.5	0.3
20	S11/45-22b	a	42.0	9.8	---	60	---	155	---	38	68	0.4	12.0
21	S9/46-35a	a	11.0	5.8	---	87	---	155	---	24	55	4.5	12.0
22	S9/46-20a	a	18.0	2.0	---	149	---	212	---	67	87	3.2	11.0
23/A	S13/47-35a	b[8]	1.37	0.58[9]	7.40[9]	---	0.26[9]	5.38[9]	---	1.98[9]	2.23[9]	---	----

FOOTNOTES:

(1) Refer to Figure 2 for Locations.
(2) Estimated in Gallons Per Minute.
(3) Micromhos at 25°C; computed by dividing solids content by .07.
(4) Calcium, Magnesium.
(5) Total Disolved Solids as Residue.
(6) Calculated.
(7) Malmberg and Eakin, 1962.
(8) Classen, 1983.
(9) Equivalents Per Million.
(10) Residue at 180°C.

Note: All results in parts per million unless otherwise specified.

acre-feet per year, which is considerably less than the current annual demands for the town of Beatty (Malmberg and Eakin, 1962).

2.4.3 Amargosa Desert

Amargosa Desert is located to the south of the proposed Bullfrog/Montgomery Shoshone Project site. The valley fill includes alluvial fan deposits, stream deposits, playa deposits and dune sand. The total thickness of these deposits is not known, but may be on the order of 2,500 feet southwest of Lathrop Wells, which is about 30 miles southeast of the present area. The coarse deposits in the valley fill are the principal source of groundwater in the valley.

Recharge to the Amargosa Desert has been estimated by Walker and Eakin (1963) to be on the order of 24,000 acre-feet per year. A substantial portion of this recharge is thought to be supplied by underflow through the Paleozoic carbonate rocks. This underflow is derived from a number of sources including Western Jackass Flats and Oasis Valley (Winograd and Thordasen, 1975). Considerable recharge is also supplied by direct precipitation and snowmelt within the drainage area.

Discharge occurs predominantly along a fault controlled, 10-mile long spring line at Ash Meadows. Ash Meadows is located in the east-central part of the Amargosa Desert, about 40 miles southeast of the project area. The combined discharge from these springs is estimated to be about 17,000 acre-feet annually (about 10,600 gpm). Discharge also occurs as evapotranspiration and to a lesser extent as underflow and discharge from irrigation wells.

A substantial amount of groundwater is held in storage in the upper 100 feet of saturated deposits within the Amargosa Desert. This water is readily available in and adjacent to the Ash Meadows area, but availability varies greatly outside of this area.

Information for several wells located relatively close to the project site is summarized in Table 2.

TABLE 2

Map No.	Sectional Description	Total Depth (ft.)	Land Surface Altitude (ft.)	Depth to Water (ft.)	Date
23/A	S13/47-35a	575	2788	282.3	7-12-62
23/B	S14/47-24d	484.1	2608	253.1	7-12-62
23/C	S14/48-32a	177.8	2542	--	--

As noted, depth to groundwater in these wells was measured at between 250 and 300 feet below the land surface. The well yields are on the order of 100 to 200 gpm with drawdown in well 23/A measured at 43 feet. A well constructed in T15S, R49E, Section 22 reported a yield of 300 gpm with a drawdown of 100 feet (Walker and Eakin, 1963).

Groundwater level contouring performed by others (Walker and Eakin, 1962; Winograd and Thordarson, 1975; Thomas and others, 1986) indicate that groundwater within the valley fill is moving southeastward along the axis of the Amargosa Desert. The slope of the water table surface generally conforms to the slope of the land surface. However, the gradient of the water surface commonly is somewhat less than that of the land surface. It has been reported that, in general, the depth to water in the Amargosa Desert increases northward. Local variations occur and depend on the head in the water-bearing zone developed for any particular well (Walker and Eakin, 1963).

Groundwater development has generally been in the southern and central portions of the Amargosa Desert, particularly south of Lathrop Well. This development has included numerous wells installed for irrigation and a few wells for stock watering, public supply and exploration.

The chemical quality of groundwater within the Amargosa Desert varies according to the recharge areas. The water in the northern portion of the Amargosa Desert near the project site is described by Winograd and Thordarson (1975) as a calcium-magnesium-sodium-bicarbonate type water and most likely comes from the Oasis Valley area. A chemical analysis of groundwater from Well 23/A is provided in Table 1.

2.5 Local Surface Water Conditions

The site is located in a tributary drainage to the Amargosa River. Located in the area bounded by Busch Peak, Ladd Mountain, Paradise and Montgomery Mountains, and Rainbow Mountain; the drainage above the proposed facilities consists of approximately 4.7 square miles.

There are no perennial or intermittent streams in the area of the mine site, except for the Amargosa River, located approximately 3.5 miles to the east. Runoff from the site flows to the south via an ephemeral drainage to a confluence with the Amargosa River approximately 9 miles away.

Runoff from the project site is limited to short periods after high intensity storms or rapid snow melt. As is typical of much of the southwestern Nevada area, this is

due to limited precipitation depths, high evapotranspiration and infiltration rates, and extremely antecedent soil moisture conditions (Riggs and Moore, 1965). Average annual precipitation in the site area is approximately 4.6 inches. The 100-year, six-hour precipitation depth is 1.8 inches, which is relatively low compared to most thunderstorm-prone areas in the United States. An evaluation of the mean annual runoff from the ungauged mine site drainage, based on a precipitation-elevation relationship methodology presented by Riggs and Moore (1965), indicates no yearly surface water yield.

Flooding potential associated with the site area is expected to be quite limited. During normal runoff conditions, surface flows will be conveyed around the site in an existing channel along the base of the Montgomery and Paradise Mountains. Estimates of the expected peak flows for the drainage above the site, generated by the Soil Conservation Service unit hydrograph method for selected return periods, are presented in Table 3. These estimates are presented as order of magnitude values and should not be used for design purposes, due to the use of preliminary soils and vegetation data and lack of adequate topographic control. It is felt that the results of the unit hydrograph method, presented in Table 3, are representative of the types of flood peaks which would result from short duration, high intensity storms for this area.

TABLE 3

Estimates of Peak Flows for Selected Return Periods

Return Period	Precipitation Depth (in.)	Curve Number	Time of Concentration (hr.)	Drainage Area (sq. mi.)	Storm Duration (hr.)	Peak Flow (cfs)
5-yr.	1.05	68	0.62	4.7	6	7.3
10-yr.	1.25	68	0.62	4.7	6	29.0
25-yr.	1.45	68	0.62	4.7	6	55.3
50-yr.	1.60	68	0.62	4.7	6	77.8
100-yr.	1.80	68	0.62	4.7	6	124.3

3. ENVIRONMENTAL CONSEQUENCES & MITIGATIVE MEASURES

The primary objective of this analysis was to identify the significant environmental consequences which would result from the construction, operation and reclamation of a selected siting of the various project components. Following this appraisal of potential impacts, the ultimate purpose of the technical evaluation was to develop conceptual design options and recommend various actions or siting constraints that would substantially mitigate the effects of a recognized impact.

Inherent within many aspects of the proposed project are engineered elements which mitigate the potential environmental consequences discussed herein. It should be recognized that the potential for environmental impacts to the hydrologic regime are first discussed without considering the levels of protection afforded by the engineered design of the ore processing-disposal schemes. This approach allows for a subsequent appreciation of the degree of mitigative effort which is already integrated into the operational plan, or which could be implemented to reduce the impacts recognized. The mitigative measures introduced in the proposed Plan of Operations, and those presented for further consideration are discussed separately.

In a generic sense, with no direct consideration for the local hydrologic setting or the design of the project components, the following are those factors related to the proposed project which appear to have the greatest risk of impacting the existing characteristics of the hydrologic systems:

- Disposal of mill tailings and spent process fluids in the tailings disposal facility and the potential loss of fluids to the underlying groundwater system. dewatering

- Potential loss of process fluids to the underlying groundwater from the leach pad and pregnant and barren solution ponds of the leaching facility.

- Possible changes in groundwater quality resulting from the migration of infiltrated precipitation and runoff through the waste rock dumps and subsequent introduction of such seepage into the groundwater regime.

- The potential water quality effects of extended residence and exposure time of water captured in open pits. This water could originate as runoff, precipitation and/or groundwater discharge.

- The potential effects caused by the extended withdrawal of groundwater for use in the milling circuit and as a supplement to the town of Beatty's water supply. These effects include changes in spring flows, lowering of the water table in existing wells due to pumping of the production well field and possible consumption of a nonrenewable resource.

- ° Changes in surface water quality and flow.
- ° Risk of highway stream crossing failures and flooding in the area of the mine and process facilities.
- ° Increase in soil erosion, stream bed scour and sediment loading.
- ° Failure of the tailings dam or overtopping of the tailings structure or solution handling ponds.
- ° Long-term stability of the stream channel diversions and potential for channel migration.

3.1 Proposed Project

The proposed plan includes five major components which may potentially impact the hydrologic systems. These include the open-pits, a millsite (with an ore processing facility, a leach pad and a tailings disposal facility), waste rock dumps, surface water diversion system and the development of the groundwater resource. Each of these elements poses a unique set of environmental consequences which can, to varying degrees, be mitigated by applying different methods of controlling surface water runoff and seepage generation, and migration.

3.1.1 Open-Pits

There appears to be two potential environmental impacts associated with the open-pit excavations. The

first involves the simple retention of runoff, precipitation and/or groundwater discharge in the excavations. The net hydraulic effect of such retention is dependent upon the state of the natural groundwater setting prior to mining. At this time, exploratory drilling has not shown that the emplacement of the Bullfrog/Montgomery Shoshone pits will result in groundwater discharge to the pit floors. Due to the apparent lack of groundwater within the two proposed pits, combined with the limited watershed area and proposed surface water diversion, the proposed action probably will result in a negligible hydrologic effect. The only observable change may consist of minor infiltration of ponded precipitation in the pit bottom.

Should groundwater be encountered, it could result in groundwater discharge to those pits during and after active mining. The impacts on the local bedrock groundwater system would be the loss of water in storage within the aquifer, with subsequent modifications in groundwater levels, gradients and recharge-discharge relationships. Once dewatering activities ceased in the pits, the movement of water to or from the pits would be dependent upon the amount of runoff and direct precipitation received by each excavation. With

only direct precipitation contributions, the level of water in the pits would be expected to express the local groundwater table.

The second potential environmental consequence of open-pit mining involves groundwater quality. As discussed above, the probability of water accumulating within the pits will be minimal unless groundwater is encountered. The long-term exposure of impounded water to the walls and floors of the open-pits may affect water quality. In such oxidizing environments, with the presence of sulfides in the mineralized rock, it is common for measurable increases in the acidity and dissolved iron and sulfate content to occur in the ponded water. With the pit water as a potential source of groundwater recharge, the consequence is obvious.

Due to the limited amount of hydrogeologic data available on the bedrock aquifer, the appraisal of the long-term effects of mining upon groundwater quality and quantity can only be generic in nature. First, the transmissivity of the bedrock aquifer is probably quite limited, with groundwater flow and storage, if any, occurring within the fractures of the rock mass. Should water quality changes occur at the open-pit locations, the transport of such waters away from the

mining area probably will be limited. During this potential migration of more acidic water through the groundwater regime, some buffering would be expected. To what level this buffering effect would occur is not known. Any increase in sulfate concentration can be expected to remain in transit in the groundwater system, but dilution would tend to reduce the concentration.

The capability of open-pit environments to generate acidic waters with elevated sulfate and heavy metal concentrations is dependent upon the character and concentration of pyrite in the ore and host rock. In the case of the Bullfrog/Montgomery Shoshone ore bodies, pyrite is not abundant owing to its general alteration to limonite (Ransome and others, 1910). The concentration of pyrite is not considered anomalously high or capable of creating a serious acid mine drainage problem.

If a substantial quantity of groundwater is encountered, the mitigation of water quality degradation problems could be accomplished by controlling the quantity of water in residence to limit stagnation. The problem of selecting additional mitigative measures to limit long-term water quality impacts caused by open-pit mining would best be solved by instituting

a monitoring program to analyze the water balance and water quality changes in the open-pit areas. If instituted, this program should include an appraisal of water quality changes in water ponded in the pits, and measurements of dewatering volumes, precipitation and diverted runoff. These data would provide a basis by which the proper combination of diversion and retention could be selected. Obviously, this effort would only be necessary if substantial quantities of water accumulate in the pits.

In summary, the potential environmental consequences resulting from the emplacement of the open-pits are not considered to be significant. With the emplacement of the proposed surface water diversion system, a substantial retention of flood waters in the Bullfrog pit will not occur, thereby eliminating any subsequent water quality effects. With no groundwater discharge to the pits anticipated, the overall hydrologic effects of the open-pit excavation is minimal. If groundwater is encountered, appropriate mitigative actions can be implemented to assure that minimal environmental effects will result.

3.1.2 Waste Rock Dumps

The proposed project includes the use of two dump sites; a 20.0 million ton dump on the lower slope of

Black's Peak and a 200.0 million ton dump to the south and southwest of Ladd Mountain. These waste rock dumps will intercept small natural drainage paths. These drainages experience short periods of flow after high intensity storms or rapid snow melt.

The potential environmental consequences associated with waste rock disposal is the generation of acidic mine drainage and the subsequent recharge of such waters to the local groundwater regime. The process of generating lower quality waters can be initiated by the infiltration of runoff or direct precipitation migrating through the waste rock mass. The degree to which water quality changes occur is dependent upon the availability of soluble constituents, sulfide concentrations and the availability of oxygen necessary for the reaction of sulfides to sulfates with a resulting decrease in pH. With lower pH, heavy metals can more readily be mobilized.

Due to the vast increase in surface area created by the breakage of the waste rock prior to disposal, the potential for water quality degradation is more distinct than that anticipated for the open-pits. However, the potential for such changes must be weighed in light of the expected low pyrite concentration of the waste rock, and the arid environment

of the site. The natural segregation caused by end-dumping of the waste rock will enhance the permeability within the rock mass, thereby facilitating any underflow and reducing residence time.

The environmental consequences on the local hydrologic systems caused by the waste rock dumps are not considered to be significant due to the following: 1) adequate surface water diversion is provided for the large Bullfrog waste rock area; 2) groundwater probably is contained in a low permeability, fractured bedrock aquifer at a considerable depth below the dump sites; and 3) the arid climatic setting probably precludes the generation of substantial quantities of seepage through the waste materials.

3.1.3 Millsite

For the purpose of this evaluation, the proposed millsite facility can be separated into three major components which possess the capability to affect local water quality. Following the crushing and grinding of the ore, it is subjected to a series of processes designed to ultimately extract the gold content. In brief, these processes include cyanidation utilizing a carbon-in-pulp method, followed by carbon stripping using a solution of

sodium hydroxide and sodium cyanide. This process of gold extraction constitutes the first component capable of affecting water quality. The second component is the dump leaching facility. This facility will consist of run-of-mine material placed on engineered, geomembrane-lined leach pads along with associated barren and pregnant solution ponds. The leach fluids will consist of a dilute sodium cyanide solution, with the pH maintained between 10 and 11 with lime. This system will be designed as a zero discharge facility, with geomembrane lined solution ponds. The remaining component of the millsite facility is the proposed tailings disposal area. This disposal impoundment will receive a slurry of suspended, finely ground rock mixed with mill wastewater. The facility will be designed as a full containment structure with a clay amended soil liner placed on the upstream dam face and on the impoundment floor.

Due to the inherent necessity to fully contain the solid and liquid slurries and reagents involved in the ore processing, the potential for the release and subsequent loss of such materials to the underlying groundwater system or to the surface water regime is reduced. Due to the economic losses which could result from a breach in the ore processing circuit, it

would be quickly remedied, with a reduced degree of environmental impact resulting. The proposed handling of the reagents used in the process should not result in any groundwater or surface water quality changes, if accidental spills are handled in an expeditious manner. For the first millsite component, the mineral extraction process of cyanidation and carbon stripping in the mill proper, no significant hydrologic consequences are anticipated.

The proposed heap leaching facility constitutes the second major component which possesses the capacity to induce changes in water quality. The potential for such impact can be quantified, in part, by analyzing the proposed engineered elements of the system and the hydrologic conditions.

The dump leaching facility, as described by St. Joe Gold Corporation in the Plan of Operations, utilizes the most current technology and materials now in common use by the mining industry. The full containment of the alkaline, cyanide-laden solutions is critical to the economic viability of the system. The pregnant solutions carry the gold content and the barren solutions contain costly reagents. These factors encourage the operator to construct and operate a no discharge facility.

By far the most critical aspect of the leaching system in terms of groundwater protection is the defensive lining systems of the solution ponds. On the pads proper, small hydraulic heads result from the sprinkling of the leach solutions. These solutions percolate the ore mass and are normally routed from the pad by a series of collection ditches. For significant solution losses to occur, punctures or split seams in the liners must be present and the subsurface would need to be permeable under a relatively low head. Much more significant is the integrity of the solution ponds, where the hydraulic heads are more pronounced. These ponds are normally below grade, sometimes making more permeable, horizontally layered units of an alluvial formation more available for seepage migration.

As discussed in the Plan of Operations, the proposed solution ponds will be geomembrane lined with leak detection systems. A 12-inch layer of 10 percent bentonite-amended clay will form the liner base. On top of this base will be a 6-inch layer of crushed rock containing the leak detection system, overlaid with a 60-mil HDPE liner. The pads will be a single liner design. A 60-mil HDPE liner will be installed over a 6-inch layer of 3/4-inch rock containing leak

detection piping. An 18-inch layer of crushed drain rock will be laid on top of the HDPE liner for tear protection.

Prior to discussing the local hydrogeologic conditions associated with the leaching facility, the groundwater protection elements of the tailings disposal facility are discussed. This is due to the proximity of the two facilities and the fact that only preliminary hydrogeologic data are available at this time.

The proposed tailings disposal facility involves the construction and operation of a full containment structure. The facility, as described in the Plan of Operations, will be constructed of overburden material and have a clay amended soil liner on the dam face and on the impoundment floor.

The site specific geotechnical and hydrogeologic conditions which underlie the proposed tailings disposal facility are not fully known, but general assumptions can be made based on the environmental and geologic setting, and available preliminary geotechnical data (Call and Nicholas, 1988).

The proposed leach pad and tailings disposal facilities are underlain by silty gravels to a depth of at

least 100 feet (T. Ryan, personal communication, 1988). The silty gravels are moderately to highly lime cemented. Of fifteen samples subjected to laboratory sieve analysis, ten classified as silty sands, with the remainder classifying as well graded sand, silty gravel or clayey sand (Call and Nicholas, 1988). Alluvial deposits of this type typically contain permeable lenses of sand and gravel, and a subordinate amount of fine grained, less permeable units of silt. Condemnation drilling performed by Dallhold Resources, Inc. indicate that the alluvial deposits are about several feet thick beneath the northeastern portion of the proposed leach pad area and more than 700 feet thick beneath the southwestern portion. The total thickness of alluvial deposits beneath the proposed tailings facility is about 150 to 350 feet. Limited hydrologic information indicates that there is no groundwater within the alluvial deposits beneath these facilities. Groundwater is first encountered within the bedrock at a depth of about 500 feet below the ground surface.

Considering the hydrogeologic conditions described above, the natural setting affords a moderate degree of hydrologic isolation. The presence of intervening silty units in the profile would retard the downward migration of seepage. However, the existence of more

permeable, intercalated sands and gravels may present lateral and vertical seepage pathways from a system not designed to encounter and control such seepage activity. The moderate depth to groundwater also affords a degree of protection from potential seepage losses. With the intervening silts and moderate depth to groundwater, there is a limited potential for degradation of the basin resources.

For the leaching and tailings disposal facility, the potential consequences of seepage losses are similar. If such losses were to occur, the result could be a local change in groundwater quality and the specific recharge to the natural system of the affected seepage volume. The water quality of the seepage from both sources would be similar, with an elevated concentration of free and complexed cyanide in solution, an elevated pH and an increase in the concentration of common ionic constituents. Seepage would be expected to move slowly in a southerly direction, with a marked reduction in cyanide concentration and decrease in pH occurring. Within a few hundred feet of the source, the significant water quality problem probably would be the elevated concentrations of common conservative ions, such as sulfate and chloride.

Several mechanisms act to reduce the concentration of cyanide as it migrates through the subsurface. The

rate at which a constituent moves in a groundwater flow system is controlled initially by the input history. Later, the physical processes that control the flux of the constituent are advection and hydrodynamic dispersion. The loss of solute mass in the flow system will also occur as a result of chemical or biochemical reactions.

The rate of movement of the cyanide in the groundwater can be estimated by calculating the advective transport rate, if sufficient data are available. Advection is the component of solute movement attributed to transport by the flowing groundwater. The rate of transport is equal to the average linear groundwater velocity. The process of hydrodynamic dispersion occurs as a result of mechanical mixing and molecular diffusion.

The natural attenuation of the cyanide is the result of chemical and biochemical reactions taking place in the fluid medium, as well as chemisorption reactions taking place between the solute and the soils and aquifer material.

Perhaps the most important chemical property of soil is the ability to retain and exchange positively charged ions on soil colloid surfaces. Cation

exchange reactions are reversible, or nearly so. The cyanide ion, being negatively charged, is not subject to cation exchange reactions.

In contrast, anions can be retained by soils through a number of reactions, some of which are purely electrostatic. These electrostatic reactions include attraction of solutes to positively charged sites on a surface, and repulsion if a surface carries a net negative charge. Layer silicates in the clay fraction of soils are normally negatively charged, so that anions tend to be repelled from the mineral surfaces. Soils, however, contain a variety of solids, including the layer silicates, that develop both negative and positive charge, often simultaneously. An anion approaching soil solids may, thus, be subjected to simultaneous repulsion by negatively charged surfaces and attraction to positively charged sites on clay edges. The capacity of soils to absorb anions increases with increasing acidity, and at all pH values, the divalent ion is absorbed to a greater extent than the monovalent ion, as would be expected on the basis of electrostatic attraction forces alone.

The sum result of the movement of seepage containing cyanide through the groundwater system is a large-scale reduction in concentration and toxicity within a

relatively short distance from the source. With proper mitigative action, monitoring and contingency planning, the proposed facilities could be operated in a manner compatible with the necessity to protect groundwater quality.

In addition to the groundwater protection elements within the proposed conceptual tailings disposal facility design, the following should be considered as mitigative actions to reduce the risk of hydrologic effects. A final appraisal as to the significance of these factors should be contingent upon obtaining additional site specific subsurface data, intercepting the subject conditions or verifying operational compatibility.

- The proposed use of clay amended soil liners poses some problems in assuring adequate seepage protection. In preparing the amended soil for placement, a confirmation that the materials are thoroughly mixed is essential. The operator must also confirm that the application of the soil liner provides a low permeability barrier to seepage movement. In many cases, this assurance can only be acquired through the use of numerous field tests. Consideration should be given to the use of artificial geomembrane lining materials in lieu of the clay amended soil.

- The proposed tailings dam design is a full-containment concept, with no provision for

underdrainage. Such designs are typically subject to long-term seepage problems, with tailings fluids in retention long after disposal ceases. With the placement of liners and drains under the dike structure, the impoundment can be allowed to drain, thereby eliminating the long-term risk of seepage loss. Such drains have the added feature of assuring a low phreatic surface in the embankment, resulting in a safe, stable earthen structure.

° The proposed design does not provide for the collection and return of fluids passing through the dam structure. With the clay amended liner on the upstream dam face, a limited amount of seepage would pass through the embankment, exiting at or near the downstream toe. Provisions for the collection and return of this seepage should be part of the conceptual dam design.

° With moderate to steep slopes of the dam faces typically constructed, the application of a properly compacted soil liner at a thickness of 12 inches would be very difficult. The design should call for a gentle slope of the upstream dam face of 3:1 (horizontal to vertical) or less, or a thicker liner to allow placement in horizontal lifts.

° After the placement of a clay amended liner, the seepage barrier will be subject to drying and possible cracking due to desiccation. Such an occurrence would seriously affect the integrity of the liner. The desiccation process can be inhibited by placing a mantle of earthen borrow over the compacted liner.

° The proposed master surface water diversion system will provide adequate protection from

runoff originating in the watershed upstream of the tailings disposal facility. However, no provision for adequate dam freeboard to contain on-site collection of the design storm is stated. With the catastrophic effects of dam failure, consideration should be given to providing freeboard that would contain a storm well in excess of the 100-year, 24-hour event.

° Accidental breaks in the tailings slurry and reclaim pipelines constitutes a significant environmental hazard. The pipeline corridor should be bermed to prevent intrusion of local runoff and uncontrolled escape of tailings slurry or reclaim water. Catchments should be provided at low points along the corridor to temporarily contain a breach. At the highway crossing, the operator should consider placing the service pipelines within a culvert or casing.

Hydrogeologic characterization, monitoring and contingency planning is an integral part of any sound groundwater protection program. Such action can be considered mitigative in the respect that proper detection and remediation of any on-site seepage problem mitigates the risk of impacting the downgradient groundwater resources. The following is a recommended course of action associated with the investigation, monitoring and contingency planning of the St. Joe Gold Corporation millsite:

° Prior to final design and construction, perform a sufficient level of hydrogeologic characterization to confirm that the facilities are

designed and constructed to protect the groundwater system.

- Initiate a baseline water quality monitoring program to establish what the character of the groundwater is prior to operation. This program should consider possible seasonal variations.

- Periodic measurements of depth to water in nearby wells and rate of spring flows.

- Installation of a monitoring system prior to operation.

- Thorough characterization of the dissolved constituents of the leach solutions and the tailings water, followed by establishment of indicator parameters.

- Initiate a program of monitoring for seepage migration by measuring for changes in indicator parameters and groundwater flow behavior.

- Comprehensive contingency plan which defines the triggering mechanisms which would initiate remedial action and discusses remedial options which are compatible with the facility design and hydrogeologic setting.

In reference to the proposed conceptual design of the dump leach facility, several aspects have been identified which may have an influence on the integrity of the system. These aspects generally deal with specific design details which are normally refined during the final design process. Our intent in discussing

these details herein is to assure that the environmental aspects are fully recognized and ultimately considered.

- The apparent compatibility of the 60-mil HDPE liner, the 3/4-inch crushed rock underliner and the 18-inch thick overdrain will need close scrutiny. The angularity of the crushed rock could induce punctures and tears in the artificial liner. The compatibility of the various components is normally confirmed through laboratory testing.

- The proposed construction of a 12-inch thick amended soil liner in the pregnant solution pond will encounter the same problems discussed above for the proposed liner in the tailings pond.

- The operator should consider a substantially greater working capacity in the pregnant solution pond than the nominal 12-hour capacity proposed. Our experience indicates a two to three-day capacity is appropriate to account for unexpected pump breakdown or other operational problems.

- The barren solution sump should be designed in essentially the same manner as the pregnant solution ponds.

- Due to the pumping of the barren and pregnant solutions to and from the leaching facilities, containment berms and a temporary catchment basin should be considered to provide adequate environmental protection. Special provisions for these pipelines crossing under the highway should be implemented.

3.2 Water Supply Development

Water usage of about 3,000 acre-feet per year is expected for consumption in the proposed mining, milling and heap leaching activities, in addition to use in dust control and as drinking water on-site. In addition, about 650 acre-feet per year of groundwater will be developed to supplement the town of Beatty water supply. The preferred location for developing the mine supply is northern Amargosa Desert immediately south of the mine site. The target location for developing a supplemental supply for Beatty is Oasis Valley (Hydro-Search, Inc., 1988; personal communication, V. Randall, ERT, 1988).

Three potential sources of water have been identified within the valley fill deposits in the vicinity of the mine site (Hydro-Search, Inc., 1988). The groundwater conditions within these three areas, Sarcobatus Flat, Oasis Valley and the Amargosa Desert, are described in Section 2.4 of this report. The effects upon the groundwater regime within any of these three areas would be the withdrawal from storage within the aquifers, and the subsequent disposal of most of the water into the tailings pond, Beatty's wastewater system, or loss through evaporation. The use of the groundwater will result in the consumption of approximately 3,650 acre-feet per year from the regional water budget.

It has been estimated by Malmberg and Eakin (1962) that Sarcobatus Flat has an estimated perennial yield of about 3,500 acre-feet per year and approximately 24,000 acre-feet of water can be drained from storage for each foot of lowering of the water table. A limited amount of water in Sarcobatus Flat is used for stock watering and irrigation. The Sarcobatus Flat alluvial aquifer may also contribute water to springs in the Bullfrog Hills. One of these springs, Indian Springs in Section 26, T11S, R46E, is a source of municipal water for the town of Beatty. Withdrawal of water from the southern portion of Sarcobatus Flat, in the quantity required to supply production needs, may impact spring flow at Indian Springs, which lies at an elevation approximately 200 to 400 feet lower than Sarcobatus Flat.

The alluvial aquifer of Oasis Valley has an estimated annual yield of about 2,000 acre-feet per year (Malmberg and Eakin, 1962), probably insufficient to meet the total supply requirements without mining water from storage. Withdrawal of groundwater from the underlying volcanics, which may contain substantial quantities of water, could be a difficult and costly undertaking. Withdrawal from the deeper water-bearing units may induce downward transport of the shallower alluvial groundwater, impacting the shallower wells and springs and their present users.

Recharge to the Amargosa Desert has been estimated by Walker and Eakin (1963) to be on the order of 24,000 acre-feet per year. A substantial amount of groundwater may be held in storage in the upper 100 feet of the saturated deposits. Water development within the northern Amargosa Desert is limited to a few stock watering, irrigation, public supply and exploration wells. Production wells placed in the northern Amargosa Desert appear to have a substantially smaller potential for impacting the regional groundwater regime than the Sarcobatus Flat and Oasis Valley alternatives. Wells located at moderate distances downgradient of the production wells should exhibit only limited effects as a result of the pumping. Also, the present sources of municipal water for Beatty should not be impacted by withdrawal of groundwater from Amargosa Desert.

Hydrologic characterization of the local and regional groundwater regimes is an integral part of a groundwater resource evaluation. Such action can be considered mitigative in the respect that adequate characterization of the aquifer parameters and interrelationships can mitigate the risk of impacting the groundwater resource and other groundwater users. The following is a recommended course of action associated with the investigation and contingency planning of the St. Joe Gold Corporation production well siting:

- Develop and utilize an inventory of present usage, local water rights and suspected resource targets, along with a regional appraisal of the hydrogeologic conditions.
- Initiate a baseline groundwater monitoring program, including water levels and rate of spring flows, to establish the character of springs and wells that may potentially be impacted. This program should consider possible seasonal variations.
- Prior to final design and construction, perform a sufficient level of hydrogeologic characterization of the local aquifer parameters using short-term hydrologic testing.
- Subsequent to construction, initiate a program of periodic measurements in nearby wells and springs as a comparison against the baseline data.

3.3 Surface Water Control

Relative to the surface water resources, the environmental consequences resulting from the proposed development are expected to be minimal. This lack of significant impacts is due mainly to the semiarid climate and the absence of significant surface waters. As previously indicated, no perennial or intermittent streams are located in the immediate area of the facilities. Additionally, the confluence of the ephemeral drainage through the facilities area with the Amargosa River is 9 miles downstream. Mean annual flow

for the ephemeral drainage is expected to be negligible, with flow expected only in response to high intensity precipitation events, mainly as flash floods. Overall, these existing conditions would not be altered by the proposed diversion; therefore, the proposed development is not expected to significantly affect the quantity of flow through the project area.

The project development plans propose two diversion channels on the east and west sides of the facilities, sized to handle the 100-year, 24-hour precipitation event. These channels will convey undisturbed area runoff around the facilities. Design of adequately engineered diversion channels will ensure that the flash flood nature of the runoff can safely be handled, and that the system will isolate the on-site area and minimize the potential for flooding of the facilities. Conveyance of the design flows in the diversion channels should not result in any overbank flows. Flows in excess of the channel capacities would be expected only for larger than design storms. Such storms would have a larger recurrence interval and probably would be of limited duration.

Within the diversion channels, velocities of 4.5 to 14.5 feet per second may be expected. Such velocities are in excess of the maximum allowable velocity for the stream

bed materials and will result in bank and channel erosion. The occurrence of significant bank erosion may result in some lateral migration of the diversion channel under flood flow conditions. Due to the relatively flat and broad drainage bottom, and the lack of adequate armoring material, there is little to prevent the migration of the channel. Also, due to the flash flood nature of the surface water regime, the amount of stream bed scour is expected to be significant. This impact could be mitigated by incorporating engineered channel armoring in the diversion design. The armor design could include the following: graded riprap with filter blanket, graded riprap with geotextile fabric filters, geotextile erosion matting, or a combination of these options on an as-needed basis.

The operator is proposing the use of culverts to convey runoff under the highway, State Route (SR) 374. Culverts are proposed at each of the locations where the diversion channels intersect the highway. Based on the 100-year, 24-hour flows from the drainage, if each of the proposed drainage channels conveyed half of the flow, the culverts would need to be 96 inches in diameter. Due to site specific constraints, such a culvert configuration would not be practical. One method to mitigate these concerns would be to install a culvert to handle the 20- to 25-year flow, combined with the

construction of a swale in the road to handle the larger flows when the culvert overtops. In addition, the diversion channel could be transitional above and below the road so that flows which overtop the culvert would not splay over the natural surface, but would be conveyed to the downstream channel in a controlled manner.

Flow events which occur in the project drainage are not expected to significantly affect downstream flows. Once flows reach the valley floor of Amargosa Desert, reduction of the channel slope and channel losses of the flood flows are expected to drastically attenuate the flood peaks and volume. As a result of this flood attenuation, the energy of the flood flows will also decrease. Therefore, any eroded material from either above or through the mine and facilities areas should be deposited a short distance downstream. As a result, erosion from the mine site area should not cause any significant sediment loading problems downstream.

Runoff flows within the mine and facilities areas will also be conveyed and/or contained. The operator has indicated that conveyance and containment structures within the diversion control will be sized to handle the probable maximum precipitation (PMP) event. Design of runoff control and containment facilities to handle this

volume will minimize the potential probability of ponds overtopping or spillage of tailings or cyanide solutions.

Long-term stability of the stream channel diversions will be a significant concern following reclamation of the facilities. Due to the broad valley with a gradual slope toward the center, there will be a tendency for the stream channels to migrate toward the center portion of the valley. In some areas this is not a significant concern, however, in the area of the heap leach and tailings pond, such migration could result in significant erosion and sediment loading. Much of this potential impact can be mitigated through engineering design of the reclamation plans for the channels, heap leach and tailings facilities. Specific actions that can be included in the designs to minimize the potential impacts are the following: incorporation of riprap or gabion protection into the channel designs; placement of riprap along the toe of heap leach or tailings ponds; and regrading of the topography to direct flow away from the facilities.

3.4 Analysis of Waste Rock Dumps

Four waste rock siting schemes are presently being considered for the Bullfrog/Montgomery Shoshone Project.

These siting options are depicted on four large Fluor Daniel site plans (Drawing Nos. 470101-00-5-010A through -013A), with descriptions of each alternative presented in a March 31, 1988 Fluor Daniel memorandum from Mr. J. Nick, Jr. to Mr. F.P. Howald. The options are identified as Preferred Case, Option 1A, Option 2A and Option 3A. Four additional options, consisting of a 25 percent expansion of each of the waste dumps listed above, are also being considered. An appraisal of the environmental consequences of each alternative siting location is presented below, followed by a comparative discussion concerning the set of waste rock disposal siting options.

3.4.1 Preferred Case

This option differs from the option originally submitted for permitting, in that the dump has been extended approximately 1,000 feet more to the east. This eastern extension has resulted in some substantial adjustments to the layout of the crushing/mill buildings area. These adjustments do not appear to have any essential influence on the environmental consequences of the mining operation upon the surface water or groundwater settings when used in conjunction with proper diversion channels. We recommend that the

design storm for the diversion channels be, at a minimum, the 100-year, 24-hour event. The channels should be designed as a stable, low maintenance, self-cleaning structures which are capable of controlling and routing flood flows long after the mining operation ceases. Proper channelization and/or culverts should be provided at the highway crossing.

3.4.2 Option 1A

This alternative would move the western toe of the south dump further east. The only apparent advantage that this configuration has over the Preferred Case is the geometry of the lower segment of the western diversion channel. This option allows the diversion channel alignment to be straight immediately upstream and adjacent to the waste rock pile. In contrast, the Preferred Case proposes a broad, curving alignment for the channel off the western corner of the dump. The first option presented has a greater potential for in-channel erosion and a higher risk of channel breach and encroachment of the waste pile during extreme flood flow due to the geometry of the alignment.

3.4.3 Option 2A

Option 2A presents a waste rock disposal scheme that contains two dumps, one due east of the pit and

immediately upgradient from the millsite, plus a south dump closely sited to the location of the proposed dumps for the Preferred Case and Option 1A.

This disposal configuration does not appear to have any adverse environmental consequences when employed with an eastern diversion channel to route runoff safely to the east of the dump, millsite, leach pad area and tailings pond. The western diversion retains the same configuration as presented in Option 1A.

3.4.4 Option 3A

The waste rock dump is located south of the highway in Option 3A. This siting required the adjustment of the leach pads and tailings pond locations. These adjustments are minor, with the leach pad complex shifted to the east and the tailings pond sited further down slope on the alluvial fan surface. The siting of all these project components does not significantly alter the potential environmental consequences related to hydrologic protection.

3.4.5 Comparative Summary

As related to groundwater protection and surface water control, the variation between the siting alternatives

discussed herein is generally not significant. The only exception is the geometry of the western diversion described in the Preferred Case. As previously stated, the western diversion in this option has a greater potential for in-channel erosion and a higher risk of channel breach and encroachment of the waste pile during extreme flood flow due to the geometry of the alignment.

Options 1A, 2A and 3A, when employed with both eastern and western diversion channels capable of controlling and routing the 100-year, 24-hour event away from all mining facilities, should provide an adequate level of protection.

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